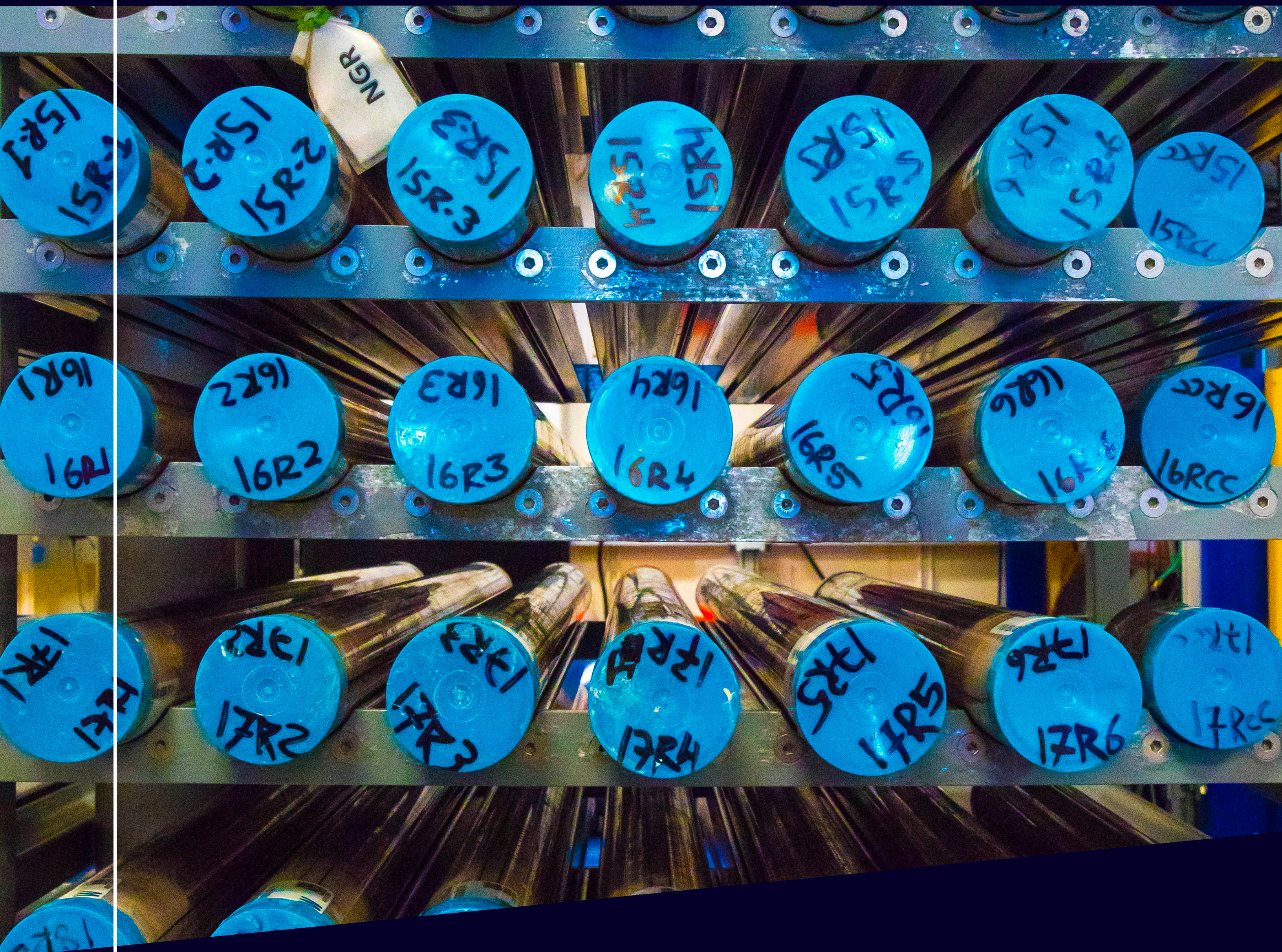
SCIENTIFIC OCEAN DRILLING

CREDIT: Sandra Herrmann & IODP JRSO



Digital Newsletter

the Drilling Dispatch

May 2024

SCIENTIFIC OCEAN DRILLING

In This Issue

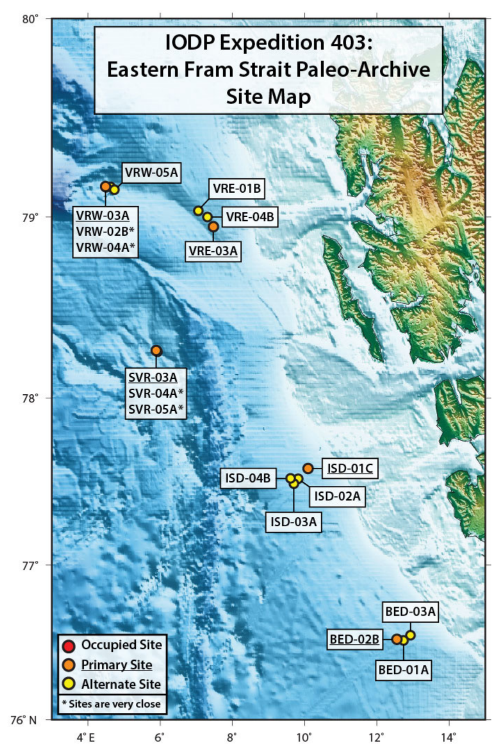
In the works...
Expedition 403: Eastern Fram Strait Paleo-Archive

Renata Giulia Lucchi and Kristen St. John,
Expedition 403 Co-Chief Scientists
Thomas Ronge, Expedition Project Manager

written by Timothy Lyons, Expedition 403 Onboard Outreach Officer

Sitting between Greenland and Svalbard is a deep-water passage that connects the Arctic Ocean with the Northern Atlantic to the south. Today this passage is best defined by the presence of a warm northward flowing current west of Spitsbergen (WSC) and the cool southward flowing East Greenland Current (EGC). By looking at the northward flowing current, which moves heat, salt, and moisture into the Arctic region, Expedition 403: "Eastern Fram Strait Paleo-Archive" will collect crucial data to ground-truth climate models of projected future CO_2, temperature, ocean circulation, sea ice, and present Earth ice sheet stability.

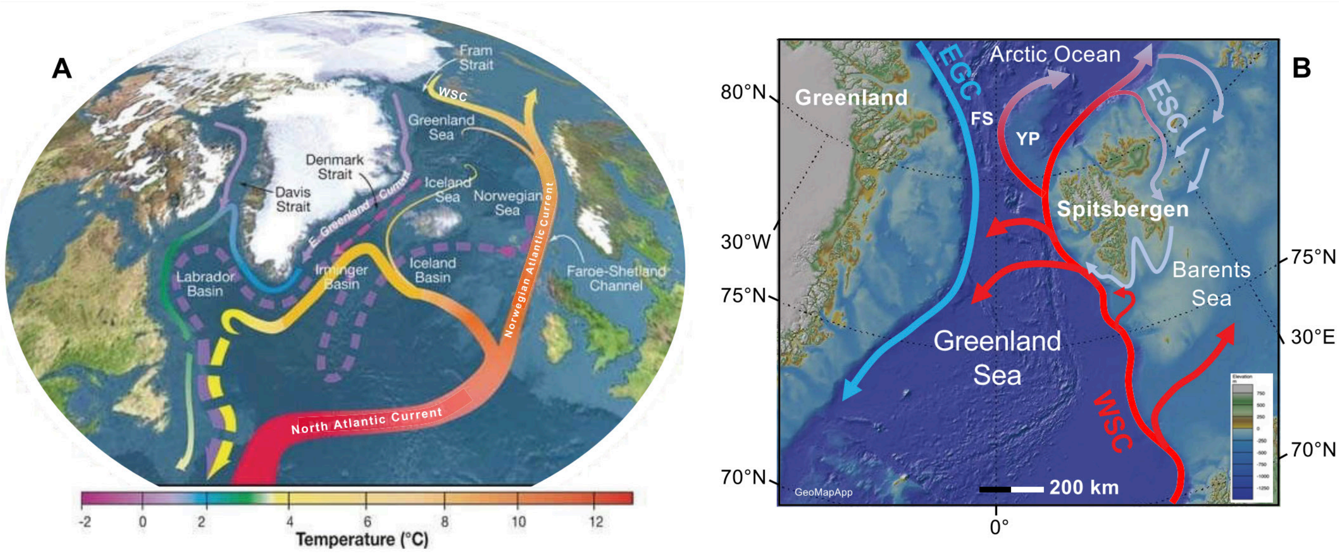
Led by Renata Giulia Lucchi (National Institute of Oceanography and Applied Geophysics-OGS) and Kristen St. John (James Madison University), Expedition 403 will depart from the port of Amsterdam in early June. Making the voyage northward, the researchers plan to drill at six primary sites along the western shore of Svalbard's largest land mass. At the deepest point, the expedition aims to retrieve samples from 738 meters below the sea floor.



Cores collected over the course of two months will address the primary objectives of Expedition 403, which are:

- to reconstruct the West Spitsbergen Current variability transporting warm North Atlantic Water to the Arctic Ocean,
- to understand the influence oceanic water patterns have on climate changes particularly during key climate transitions (late Miocene–Pliocene transition, late Pliocene–Pleistocene transition, MPT, mid-Brunhes transition, and suborbital Heinrich-like events),
- and, to measure the impact this exchange has on the Arctic glaciations, ice shelves development and stability, and sea ice distribution.

Over millions of years, sediment has collected under the influence of marine sedimentological and biological activity, advancing



Modern oceanographic configuration of North Atlantic Ocean. (A) Schematic circulation of surface currents (solid curves) and deep currents (dashed curves) that form portion of AMOC. Curve colors indicate approximate temperatures. Modified after Curry (2010). (B) Details of northernmost part of Atlantic Ocean currents' configuration. Modified after Jakobson et al. (2012). (Credit: Lucchi, R.G., St. John, K., and Ronge, T.A., 2023).

and retreating glaciers on the continental margin, and the warm current moving along the seafloor in the eastern Fram Strait. The climate proxies contained in these sediment drifts hold clues of key climate transitions, useful climate proxies of the past which, can be used as analogs for future climate transitions. Through a more detailed reconstruction of the West Spitsbergen Current and North Atlantic Water, researchers will be better able to inform the climate models that guide our future in a warming world.

While the Arctic and North Atlantic Oceans play a significant role in the climatic evolution of the Northern Hemisphere, the findings of this expedition also shine a light on the future of the South Pole. One particularly influential aspect of Expedition 403 is what can be learned from the depositional history of this region as it is applied to onshore geology, including the dynamics of the Svalbard-Barents Sea Ice Sheet (SBSIS) complex. The paleo marine-based SBSIS is considered the best analog for the modern West Antarctic Ice Sheet (WAIS). Easier to access than the Antarctic ice sheet, the paleo SBSIS record becomes an ideal laboratory to explore the effects of ice-atmosphere-ocean interactions under fast, warm climatic change. With an increasingly warming climate, the loss of stability of the WAIS is a significant concern for future global projections of sea level rise.

Expedition 403 stands out in significance not only because it will return with data to better understand some of the most pressing details of our changing climate, but also for its historic role as the last expedition of the *JOIDES Resolution* within the International Ocean Discovery Program. While the future of the veteran ship is still uncertain, the likeliest outcome is that the decommissioning process will begin in the port of Amsterdam soon after the conclusion of this expedition.

Join the Slingshot production team as they document the final IODP expedition for the upcoming feature length documentary: The Time Travelers. For more information visit the expedition page on the International Ocean Discovery Program website. Stay up-to-date with expedition news on the *JOIDES Resolution* X (formerly Twitter), Facebook, and Instagram accounts.

From the field...

JR Academy Expedition 402T: From Fire to Flood

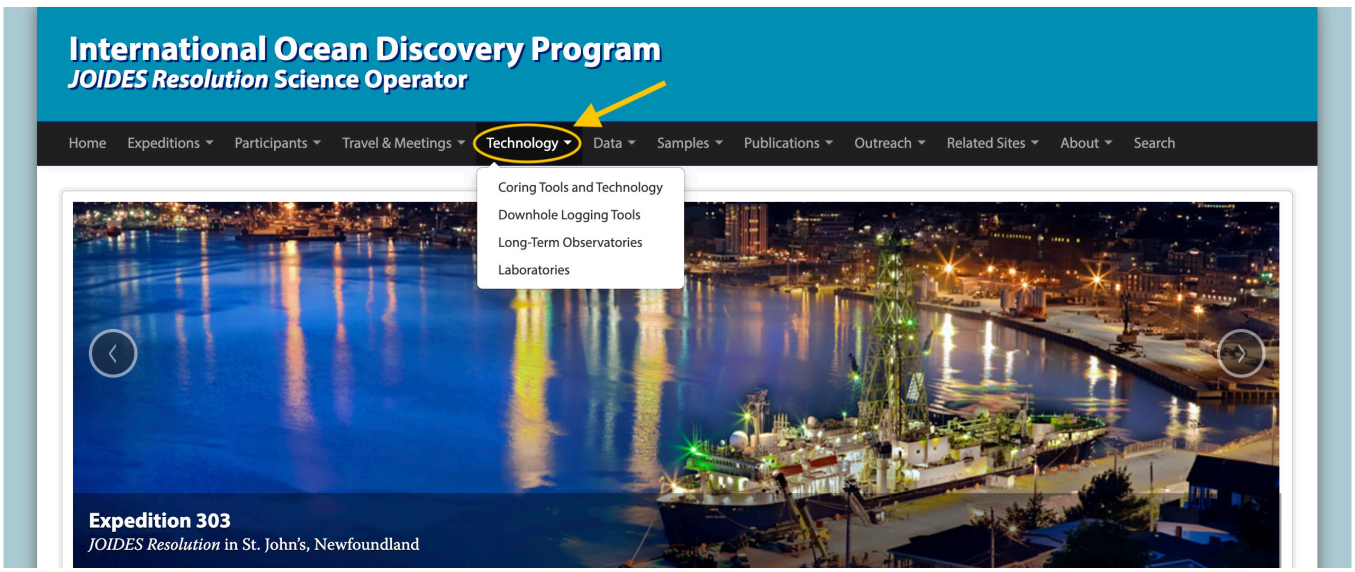
written by Clarene Davis, JR Academy 2024 participant

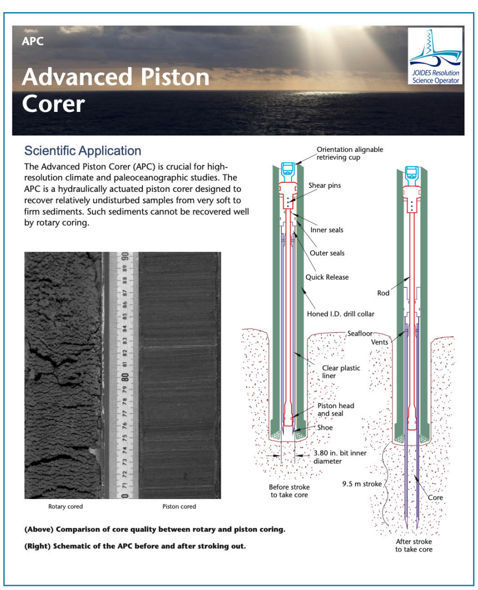
In the heart of Earth's embrace,
Where time is carved in stone,
JR Academy's young minds roam,
With geology's secrets to own.
Indigenous scientists,
Guardians of ancient lore,
Unravel Earth's mysteries,
As they've done before.
With hands that touch the soil,
Feeling stories untold,
They listen to the whispers of legends manifold.
From mountains high to rivers deep,
They trace the land's design,
Honoring indigenous wisdom,
A heritage divine.
Each rock a tale,
Each fossil a song,
Passed down through generations,
Where ancestors belong.
Their knowledge intertwined with Earth's rhythmic flow,
Guiding young geologists as they learn and grow.
In JR Academy's halls, diversity blooms,
Celebrating indigenous brilliance,
Dispelling old glooms.
For science knows no borders,
no cultural divide,
It's a tapestry of voices,
In which we all confide.
So let's cherish the geologists,
Both young and old,
Who walk in harmony with nature,
Their stories yet untold.
For in JR Academy's realm,
Geology's dance is grand,
Where indigenous knowledge and science hand in hand.

How to...

Learn more about coring and logging technologies

Scientific ocean drilling is an almost-unimaginable feat of engineering. However, thanks to the *JOIDES Resolution* Science Operator, it is possible to learn everything there is to know about coring and downhole logging technologies. Whether you're curious about the technologies available to the expedition science party, need more details for the methods section of the paper you're working on, or could simply use some help explaining what you do to curious friends and family members, the IODP technology pages have you covered! Browse through Coring Tools and Technology, Downhole Logging Tools, Long-term Observatories, and Laboratories to become an expert on scientific ocean drilling tools.




APC

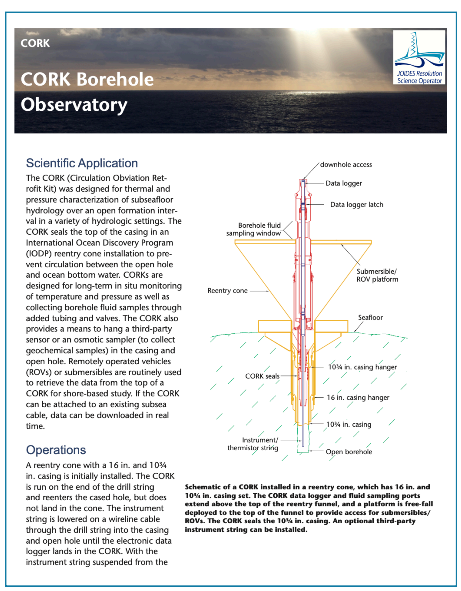
Advanced Piston Corer

Scientific Application

The Advanced Piston Corer (APC) is crucial for high-resolution climate and paleoceanographic studies. The APC is a hydraulically actuated piston corer designed to recover relatively undisturbed samples from very soft to firm sediments. Such sediments cannot be recovered well by rotary coring.

(Above) Comparison of core quality between rotary and piston coring.

(Right) Schematic of the APC before and after stroking out.


CORK

CORK Borehole Observatory

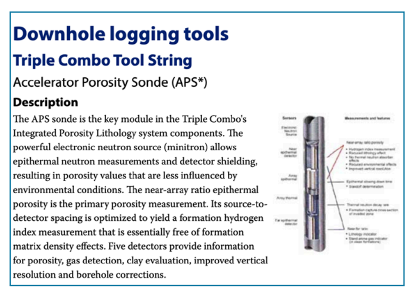
Scientific Application

The CORK (Circulation Obviation Retrofit Kit) was designed for thermal and pressure characterization of subseafloor hydrology over an open formation interval in a variety of hydrologic settings. The CORK seals the top of the casing in an International Ocean Discovery Program (IODP) reentry cone installation to prevent circulation between the open hole and ocean bottom water. CORKs are designed for long-term in situ monitoring of temperature and pressure as well as collecting borehole fluid samples through added tubing and valves. The CORK also provides a means to hang a third-party sensor or an osmotic sampler (to collect geochemical samples) in the casing and open hole. Remotely operated vehicles (ROVs) or submersibles are routinely used to retrieve the data from the top of a CORK for shore-based study. If the CORK can be attached to an existing subsea cable, data can be downloaded in real time.

Operations

A reentry cone with a 16 in. and 10¾ in. casing is initially installed. The CORK is run on the end of the drill string and reenters the cased hole, but does not land in the cone. The instrument string is lowered on a wireline cable through the drill string into the casing and open hole until the electronic data logger lands in the CORK. With the instrument string suspended from the

Schematic of a CORK installed in a reentry cone, which has 16 in. and 10¾ in. casing set. The CORK data logger and fluid sampling ports extend above the top of the reentry funnel, and a platform is free-fall deployed to the top of the funnel to provide access for submersibles/ROVs. The CORK seals the 10¾ in. casing. An optional third-party instrument string can be installed.


Downhole logging tools

Triple Combo Tool String

Accelerator Porosity Sonde (APS*)

Description

The APS sonde is the key module in the Triple Combo's Integrated Porosity Lithology system components. The powerful electronic neutron source (minitron) allows epithermal neutron measurements and detector shielding, resulting in porosity values that are less influenced by environmental conditions. The near-array ratio epithermal porosity is the primary porosity measurement. Its source-to-detector spacing is optimized to yield a formation hydrogen index measurement that is essentially free of formation matrix density effects. Five detectors provide information for porosity, gas detection, clay evaluation, improved vertical resolution and borehole corrections.

Examples of information and resources available on the *JOIDES Resolution* Science Operator website, explaining coring tools and technologies, downhole logging equipment, and long-term observatories.

FEATURED VIDEO

[The Library of Earth's History]

Developed by One World Network, this video will take you on a journey to see how the global scientific endeavor that is IODP unravels the mysteries of our planet's history and inner workings.

For your calendar

- **Addressing Future Ocean Drilling in the US (FOCUS) in-person workshop**
  (21-23 May 2024; Denver, CO, USA; learn more)
- **Submit an abstract to GSA Connects'24**
  (deadline: 18 June 2024; learn more)
- **Glacial Sedimentation School**
  (14-19 July 2024; College Station, TX, USA; learn more)
- **Plankic Foraminiferal Biostratigraphy and Taxonomy workshop**
  (19-23 August 2024; Amherst, MA, USA; learn more)
- **Future Directions for Scientific Ocean Drilling Interstitial Water Research workshop**
  (apply by 25 May 2024; Put-In-Bay, OH, USA; learn more)
- **Provide input on Future Ocean Drilling in the US (FOCUS)**
  (open deadline; learn more)

SCI COMM RESOURCE OF THE MONTH

In Part 1 of this activity, students become micro-paleontologists and learn how to use microfossils to obtain ages for cores. Then in Part 2, they learn how paleomagnetism is used to accurately date cores of rock onboard the *JOIDES Resolution*.

How old is it?

Spotlight on... Dr. Carol Cotterill

written by Maya Pincus (USSSP)

“As a child, my mom would say I was quite precocious.” Of some children, that might mean learning the violin at an early age, or growing up multilingual. For Dr. Carol Cotterill, it meant “I enjoy learning and I’ve always enjoyed learning, and I’ve always been very curious.” From the course of Carol’s life, it’s clear that this curiosity has no limits, neither in subject nor scope. If you can name it, she’s done it, though she claims “I’m sure there are other things that will come up at some point in my life that will prove to me that I haven’t come across another problem yet.”

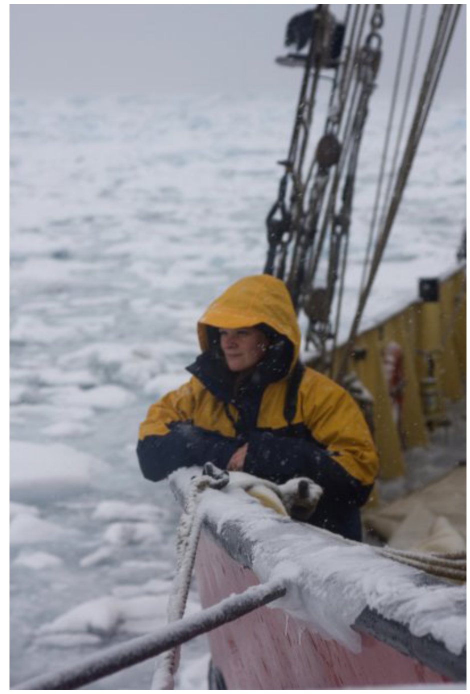
Regular readers will recognize Carol as the U.S. Science Support Program’s Associate Director of Education and Outreach, but it was “via a long and winding path I think is how I would say I got here.” It may come as a surprise that Carol’s career began quite displaced from science; the first degree she earned was in theater design, and with that training she started her own lighting company in London and worked as a scene painter for the National Theatre. For a while, she was content to let her ambitions drive her to further success in this field, but an injury to her back left her abruptly at odds with the rigorous physicality of that line of work.

Her time spent healing was also a time of soul searching. She recalled the long forgotten childhood dream of becoming a Metoc, a meteorologist-cum-oceanographer for the Royal Navy, quashed back then due to a relentless case of childhood asthma. “But it suddenly came back to me again that I really liked being by the water and I really liked being on the water… maybe there was something for me there.” The final reckoning with the path she was on came when Carol was in Melbourne, Australia as part of an exchange program. Sitting on the beach, staring out to the ocean, she thought “Maybe I could go back to university.” Talking it over with the father of her host family, his only advice was, “Yeah, you should just do it!”

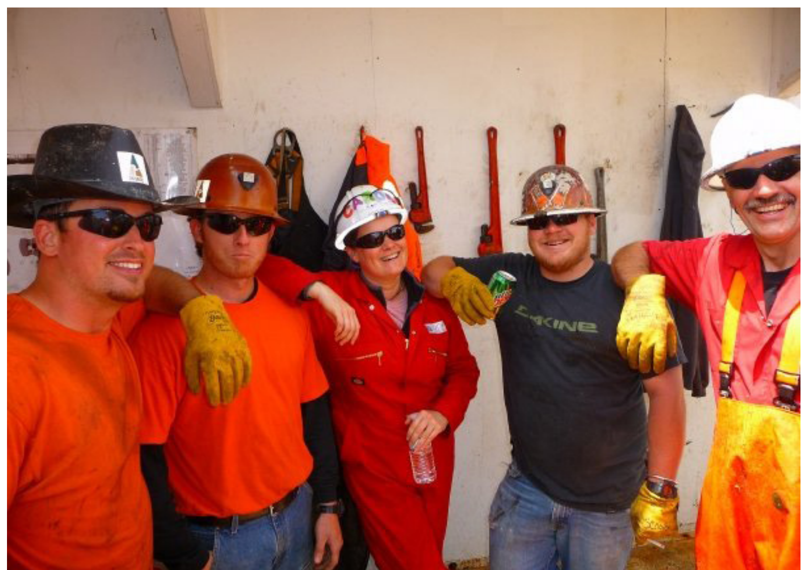
While managing her own theater company by day, she immersed herself in science classes at night, making up for the dearth of STEM-

One of Carol’s defining characteristics is her love of adventure and the outdoors (Credit: Carol Cotterill).

based O-levels she earned in high school. After just a year, she was qualified to apply for oceanography and geology programs, and was soon accepted to Southampton University to begin her second bachelor's degree. During this time in undergrad, Carol caught wind of a "really interesting PhD topic," and was approached by the lead scientist who encouraged her to apply. She accepted with excitement, and went straight from her undergraduate studies to her doctorate, analyzing neotectonics and strain partitioning of the offshore Gulf of Corinth. Before long, she was recruited for a position with the British Geological Survey (BGS), where she would spend the next fourteen years.



What delighted Carol about BGS was the diversity of problems she was tasked with. She quickly made a name for herself when two of her mentors brought her along to a meeting with a potential offshore energy client. The goal of the scientists who took her under their wing was for her to "stay in the background and listen, to see how things were done," but even their best laid plans were waylaid by one member of the client's team.



Her love of the ocean was enough to drive a career change to the British Geological Survey, where she worked as an Expedition Project Manager for ECORD (Credit: Carol Cotterill & ECORD).

Like Carol, the woman had largely remained silent throughout the meeting, but she eventually caught Carol's eye and beckoned her to a corner of the room. She took out some printouts showing interpretations of a seismic profile, and asked Carol what she thought. "Of course, me being me, I said, 'well, it's completely wrong!'" In Carol's opinion, the profile had been completely misinterpreted, failing to identify a channel that appeared quite obvious, among other errors. Suddenly she was aware that the other three gentlemen in the meeting, including her two mentors, had stopped talking and started listening, and "Bang! There goes my 'please be silent and don't say anything.'" Instead, Carol addressed the whole room and said "Actually, whoever is interpreting this has done a really bad job at interpreting the seismic data." She proceeded to explain all the things she would have done differently. It turned out that this was a test "which apparently we passed, because I have trouble keeping my mouth shut when I see that something in my opinion has been done wrong." In the end, it was Carol's outspokenness that won them the contract.

With that, Carol was assigned to the offshore wind team, where her main focus was the development of offshore ground models to help with foundation design for wind farms. This allowed her to apply her newfound skills, "integrating geotechnics and geology and geophysics" to describe buried landscapes.

She looked forward to the meetings that took place every three months where a mixed expertise group from BGS would present to clients. Carol's role was to "put all the data together and explain it in terms of past landscapes and what environmentally had happened to the land." She so deftly explained the complex science to groups of non-geologists that she earned from a colleague the designation, "the queen of Dogger Bank who tells fairy tales for a living."

An affectionate nickname was not the only thing Carol earned—she was also asked by BGS to write a document for best practices on how to run a mission specific platform for the European Consortium for Ocean Research Drilling (ECORD), which in turn led to an invitation to spend part of her time working as an IODP expedition project manager. In total, she planned and supervised five expeditions, and learned in the process that there was no such thing as a normal expedition. During her first, Expedition 313: New Jersey Shallow Shelf, the drill string got stuck in the hole and they had to cut themselves out. A cyclone passed directly over the MSP during Expedition 325: Great Barrier Reef, and an unrelated fire broke out on the ship. Planning for Expedition 347: Baltic Sea Paleoenvironment was mostly spent in consideration of the unexploded ordinance and contaminated sediment they would be drilling around. When bad weather prevented Expedition 357: Atlantis Massif Serpentinization and Life from drilling, Carol spent her time sitting in her office making a multibeam map. Reflecting on this frenzied period, her main takeaway is "I met a load of wonderful people. And I think a normal expedition now would be boring."

Carol's wanderlust fuels her creativity; each new excursion to the remote corners of the planet is an opportunity to immerse herself in the natural world and practice her photography (Credit: Carol Cotterill).

It was also during that time that "I realized that scientists can be pretty poor at explaining the science they are doing, which is usually really exciting and interesting, but they just don't have the terminology and a way to describe it." She convinced BGS to sponsor her participation in a masters program in science communication, which allowed her to return to her artistic roots by focusing not just on the exciting research her office was conducting, but also developing and carrying out strategic plans for communication, education, and outreach.

Carol's time at the British Geological Survey came to a natural conclusion when the Communications department reshuffled and the role she had grown into was no longer feasible. Conveniently, this occurred right at the time that the U.S. Science Support Program was looking to build its education and outreach team, and Carol was quickly hired. After working remotely while the COVID-19 virus ravaged the world, Carol eventually moved herself and her cats across the Atlantic to Lamont-Doherty Earth Observatory, where she expanded the onboard outreach officer program, wrote strategic communications plans, mentored new staff members, and all around used her creativity to increase the reach of the International Ocean Discovery Program.

If one thing is clear, however, it's that Carol cannot stay still for long. In her personal life, this manifests as grand adventures, traveling to exotic places to hone her photography skills, or participating in days-long athletic endeavors to raise money for charity. Hearing her tell the stories of "seeking out numerous different ways to try to kill myself," it becomes obvious that Carol is brave, funny, and passionately alive. From coming face-to-face with a bull elephant on a Namibian riverbank to signing up to skate 100 miles across a frozen Mongolian lake, Carol has demonstrated time and again that she is good at going where other people don't go, for the right reasons.

Her wanderlust is also exerting itself on her professional life. In just a few days, Carol will pack up her belongings and ship herself and the cats to Oslo, Norway. As much as she has loved her time elevating scientific ocean drilling in the public sphere, the curiosity that has driven her for so much of her life is guiding her back to research. At the Norwegian Geotechnical Institute she will return to her wind farm work, which will hopefully satisfy her "need to get back into doing science."

As devastated as we are to lose Carol as a full-time member of the team, we are eager to see where this next leg of her journey takes her. There is no doubt that she will have a resounding impact on the work of the U.S. Science Support Program, not least through the invaluable mentorship she provided to none other than this author.

Spotlight on... Dr. Lisa Tauxe

written by Elizabeth Doyle
Expedition 400 Onboard Outreach Officer

Credit: Lisa Tauxe

Drilling Through Generations: Geophysicist Lisa Tauxe's Family Legacy

Scientific drilling is a family affair for renowned geophysicist Lisa Tauxe. From her home base at the Scripps Institution of Oceanography, part of the University of California, San Diego, Lisa has sailed five times as a researcher aboard the *JOIDES Resolution* and once on its predecessor, the *Glomar Challenger*. Her husband, igneous petrologist Hubert Staudigel, has joined three expeditions.

Lisa's brother John Tauxe and his wife Katie met on Leg 100 of the Ocean Drilling Program (ODP) expeditions. And last fall, Lisa and her son Philip Staudigel, an inorganic geochemist, sailed together on Expedition 400 in the waters of Melville Bugt, along the coast of Northwest Greenland.

"I say that the family motto," Lisa said with a smile, "is drill, baby, drill." It was so even before Lisa came along.

George William Hardwick, AKA her Uncle Rocky, served in the Navy during World War II. An adventurer by nature—another trait that runs in the family—he at one point piloted a tugboat across the Pacific Ocean. After the war, he worked on a support ship for a drilling platform.

Naturally, when Lisa's two sons were still kids, they were expected to pitch in when accompanying their parents to the field. The work required getting rock samples to determine the magnetic field, using a handheld power drill, modified from a chain saw. "We labeled drill sites using letters of the alphabet," Lisa said, "so this is where my son Daniel learned his letters." Philip fondly remembers these outings.

"We had a routine: Dad would drill, mom would orient and label the samples, and my brother and me were given copious toilet paper to wrap the samples up with," Philip recounted. "I don't know how much help we actually were, but we had fun." Lisa added that when "the kids were old enough, we'd hand them the drill."

TOP: After World War II, Lisa's Uncle George "Rocky" Hardwick worked on a support ship for a drilling platform (Credit: Unknown). BOTTOM: Lisa as a graduate student and paleomagnetist on DSDP Leg 73, South Atlantic Ocean in 1980 (Credit: DSDP).

Lisa's first ocean-going expedition was as a Columbia University graduate student on Leg 73 of the Deep Sea Drilling Program (DSDP), aboard the *Glomar Challenger*. Even before then, though, she had punched her explorer's card several times over. As a Yale undergraduate studying geology, she took a class in paleomagnetism taught by a friend of her then-boyfriend. She liked it, but wanted field experience. "At that time at Yale, there was no field class and the only way undergraduates got experience was by being a field assistant for somebody," Lisa recounted. "Nobody would take me because I was 'a girl.' Fun fact," she added dryly.

But then she heard of an expedition to Pakistan. She talked her way onto the team. That work, in turn, led to her selection for Yale's Scholars of the House program that freed her from class requirements and allowed her to focus on her paleomagnetism-centered senior thesis.

Lisa's origin story overlaps with another leader in Earth science. Carl Brenner, now director of the U.S. Science Support Program (USSSP), was also a Scholar of the House, at the same time. Their professional paths have crossed ever since. "It's remarkable to me how far back we go," Carl said. "Neither of us expected we would end up in the same field, and yet now there is no one in ocean drilling whom I've known longer than Lisa. Every time we see each other we just pick up the conversation like we were in touch the day before."

Her Pakistan field work led to Lisa's earliest contributions using paleomagnetism, the study of ancient magnetic fields. She recalled tracing one magnetic reversal, beneath and along a large sandstone layer that was particularly crucial to paleontologists working in the region. The location is rich in Miocene mammalian fossils—hippos, giraffe-like creatures, antelopes, and elephants, as well as the primate *Ramapithecus*, which at the time was thought to be ancestral to the human line. Lisa meticulously documented a horizon within the sandstone, across a span of about 50 miles that was isochronous, meaning that it was laid down at the same time. With the time and place now linked, paleontologists were able to reconstruct the environment in which these mammals lived and grazed. Next, she determined the age of this magnetic reversal. Paleontologists could then use the layer to pin down the numerical age of the embedded fossils, most notably *Ramapithecus*.

TOP: Katie and John Tauxe met as technicians on their first expedition, OPD Leg 100, where he specialized in paleomagnetism and she in chemistry (Credit: ODP). BOTTOM: Hubert Staudigel, top with fellow scientists on ODP Leg 106, painting the hardhat of his colleague. The story behind this antic has been lost to time, but speaks to his mischievous sense of humor (Credit: ODP).

Her analysis markedly shifted the age of this significant fossil, from 9 million to 8 million years old, and led to her first publication as a first-year graduate student, in *Nature* no less. She has authored over 250 papers since then.

It was in Pakistan that Lisa met her soon-to-be graduate advisor, when he showed up at a rest house where her team was camped. "He was the funniest guy," Lisa said. "He had this Australian bush hat, and he comes bursting in and bellows, 'Where can I get a drink around here?' He was a very big personality, huge laugh, wonderful guy." Though he left after two years, Lisa ended up with a different, equally great advisor.

With an eventual doctorate from Columbia in hand, Lisa went west to Scripps, where she was serving as an assistant professor when she joined ODP Leg 108. This expedition, off the coast of northwest Africa, was a reunion of sorts. "I sailed with my brother John, which was super fun," Lisa said, "I was the paleomagnetist and he was the paleomagnetic technician."

Running into family on board was becoming a tradition. Less than two months earlier, Lisa's husband Hubert Staudigel sailed as an igneous petrologist, along with her brother John and his wife Katie on ODP Leg 106. Immediately after Leg 108, Lisa's adventurous spirit then threw her for a loop, in a mishap that she turned into opportunity. "I was windsurfing in raw sewage in Senegal and contracted Hepatitis A," Lisa recalled. "Because I could not have alcohol for a year, my mom said 'You know what else you can't drink for?'" And so, Lisa said, "I had a baby, my son Daniel. Then Philip came along."

Once she was a mom, Lisa said she couldn't leave her kids behind, so shifted to land-based work. Even so, she brought Philip into the field when he was nine months old. In his teens, he joined Lisa in Jan Mayen, a Norwegian volcanic island east of Greenland and north of Iceland. Philip said these outings "absolutely" shaped his career path. Now a Postdoctoral Research Fellow at Goethe University Frankfurt, his area of expertise also has family ties. "I tried to work on anything but what my parents did, just to avoid comparison. If mom studies the magnetism of sediments, and dad studies the chemistry of volcanoes, I think I just ended up splitting the difference by choosing to study the chemistry of sediments," Philip said.

Once her kids were in college, Lisa returned to sea, again applying her paleomagnetic expertise. In 2010, she sailed with IODP Expedition 318 to the Wilkes Land margin, off the coast of eastern Antarctica. Nine years later Lisa returned to coastal Antarctica, in Iceberg Alley of the Scotia Sea for IODP Expedition 382.

It was only fitting, then, that Lisa's significant contributions to paleomagnetism were recognized when she was, yes, out at sea on yet another drilling expedition. This time she was sailing in the Arabian Sea along the Indian continental margin for IODP Expedition 355.

LEFT: Lisa Tauxe on IODP Expedition 355 in 2015, cutting into the cake celebrating her election as a member of the National Academy of Sciences (Credit: Peter Clift & IODP). RIGHT: Lisa with her son, Philip Staudigel, on IODP Expedition 400: NW Greenland Glaciated Margin (Credit: Erick Bravo & IODP JRSO).

Creative COREner...
1000 Years

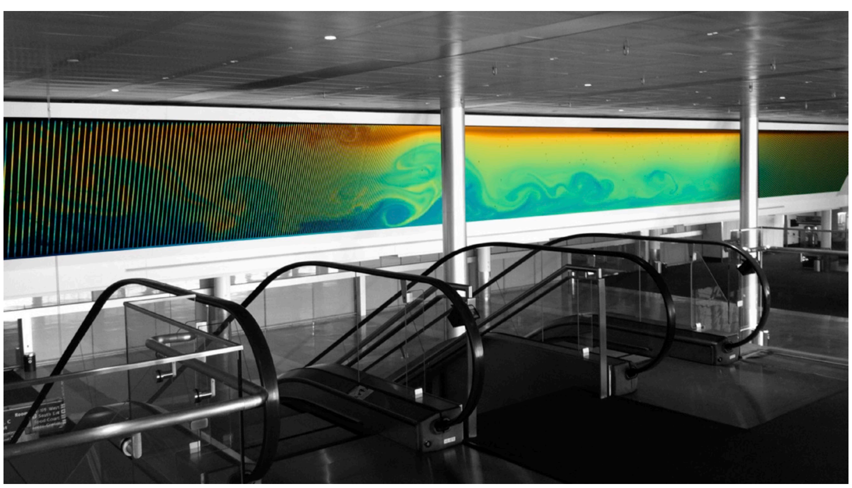
written by W. Benjamin Bray

Our sense of the ocean is often in spatial units of measure, as we think of its vast surface and profound depth. Distances in the ocean seem greater than on land because it's so much more difficult to explore. Yet time is a more pertinent measure, as it often incurs cost, and its value to us increases as we get older. So, let's consider the ocean volume in terms of both, as a flowing system thousands of miles long, and a record of our influence a thousand years deep.

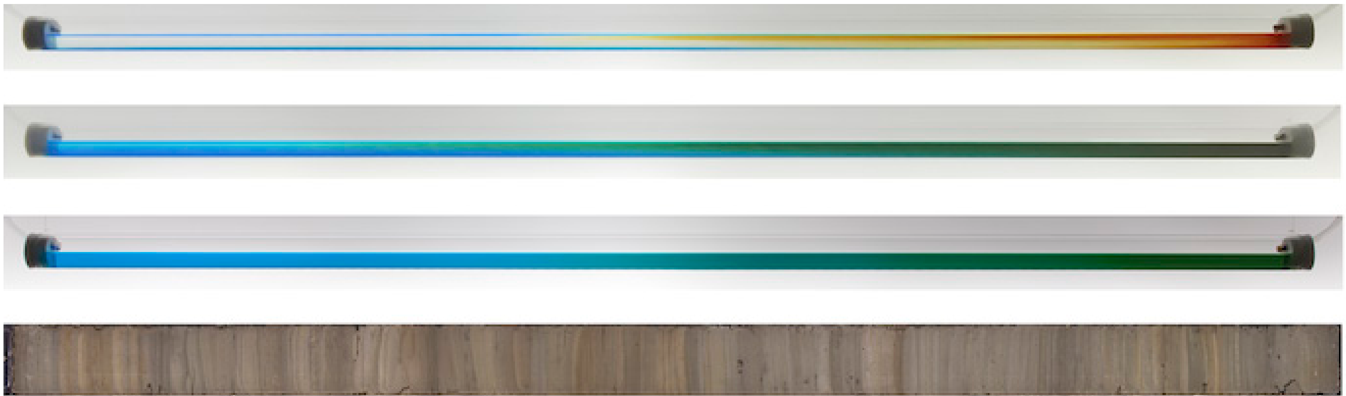
The "deep" domain of the ocean, according to many ocean scientists, is below 200m. This is the depth to which photosynthesis can be sustained - the deepest direct influence of natural illumination from the surface (the Sun). In the context of global climate, the deep ocean is the most dominant reservoir of heat on Earth, a density-driven, multi-layered network of flows connecting the polar regions. The deep ocean is essentially unfathomable, a vast common for doubt, where our relationship oscillates between rigorous debate and detached ambiguity. Like the Arctic and the Antarctic, it affects innumerable downstream climatic changes, but is far more difficult and expensive for scientists to explore and sense directly. And so, it remains a hiding place—a dark, massive, subconscious presence that lies outside the domain of what society generally perceives as under its control or as its responsibility.

Relative to human activity, however, the ocean isn't deep at all. If there were an "Anthropic Zone" in the ocean defined by the depth to which humans affect ocean chemistry and habitat, it would extend all of the way to the bottom. And because so much of the ocean is dark, we don't see the profound depths of humanity's influence. The ocean is deep relative to our knowledge of it, but also shallow relative to our influence.

The Meridional Overturning Circulation is the primary system of ocean currents spanning the entire globe, driven by temperature and salinity-dependent instabilities, and large-scale wind patterns. Cold, salty water is more dense than warm, fresh water, and when you have this vertical instability in the water column, you have overturning. This overturning flow is the strongest connection between the surface ocean and the deep ocean. A complete overturning of the Earth's oceans occurs in approximately 1000 years, the same time period over which human activity affects the Earth in the Anthropocene.



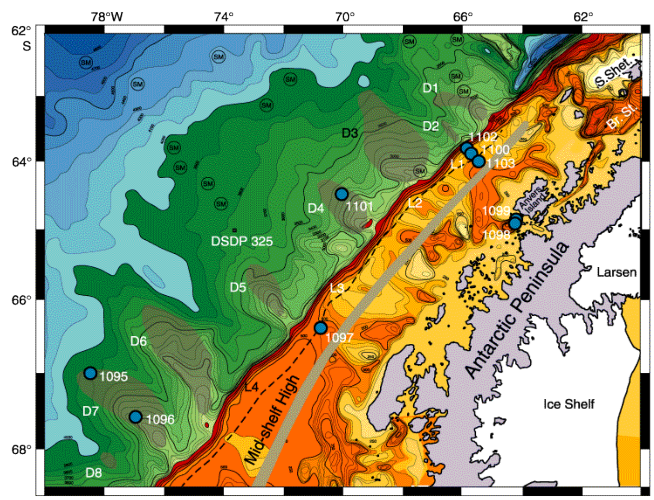
This massive display in the Boston Convention and Exhibition Center combines the flow and accumulation concepts presented in the the 1000 Years project, rendered as a 60-sec simulation (Credit: W. Benjamin Bray and Mark J. Stock).



From top: The flowing Meridional Overturning Current as three tubes, in sequential stages of flow; the 1000-year sediment core (Credit: W. Benjamin Bray).

The accompanying photos present 1000 years of overturning in borosilicate tubes 1.52m long. One tube, shown in sequential stages of flow, depicts the Meridional Overturning Circulation, with cold, downwelling seawater flowing underneath warm water full of detritus that's settling to the bottom. Melting chunks of frozen seawater dyed blue trace the downwelling, while warm espresso traces the buoyant, flowing surface current. The flowing currents mix together over 48 hours into a continuous shade of dark blue-green.

The other tube presents a sediment core: a layered collection of detritus extracted from a single location in the ocean floor. Oceanic detritus that's heavy enough and isn't recycled through ocean biochemistry eventually settles to the bottom, creating layers of sediment reflecting changes in the biogeochemical dynamics of the water column over many years. Sedimentation rates vary considerably throughout the ocean, and in the Southern Ocean just west of Palmer Land, Antarctica, the sedimentation rate is approximately 1.52mm/per year, or 1.52m per millennia, the same length as the glass tube. This sediment core was photographed by the artist at the International Ocean Drilling Program repository in College Station, TX.



The 1000-year core was collected from Hole U1098A during Ocean Drilling Program Leg 178. This map shows sites drilled during that expedition on the Antarctic Peninsula Pacific margin, with bathymetry from Rebesco et al. (1998) and showing sediment Lobes L1-L4 on the outer continental shelf, Drifts D1-D8 on the upper continental rise, the mid-shelf high (MSH), and DSDP Site 325. Br. St. = Bransfield Strait, S. Shet = South Shetland Islands. (Credit: ODP)

These depictions of the ocean in units of time and space are easier to grasp than units of influence, because the latter is more difficult to study and understand, due to its dependence on the former. But our influence on the ocean continues to reveal itself as we collect more data beyond its darkest horizons.

To learn more about this piece and others, visit the artist's website.

Call for contributions

If there's one thing that can be said about the International Ocean Discovery Program (and the Integrated Ocean Drilling Program, and the Ocean Drilling Program, and the Deep Sea Drilling Project), it's that we are a tight-knit community. Just as much as this newsletter is for you, we want it to be from you, too! In future editions we will highlight our readers by featuring the following community contributions:

- **From the Field** - Have you had an experience with scientific ocean drilling that you want to share? Write a piece to tell us your perspective "from the field" for our next edition. Bonus points if you include some pictures!

- **Scientist Spotlight** - Do you know someone who's making waves in the ocean drilling scene, whether it's a grad student or accomplished scientist? Send us a nomination! Briefly tell us why this person deserves a shout-out, and ideally how to get in touch with them. Self-nominations are also accepted.

- **Photo Montage** - We'll take any photos you want to share!

- **Creative COREner** - Scientists are creators too! Send in your paintings, drawings, digital designs, poems, short stories, sculptures, or any other ocean science art you've made.

Send your contributions (and questions and concerns) to **mpincus@ldeo.columbia.edu** no later than **May 20, 2024** to be featured in next month's newsletter.

See you next month!